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INVESTIGATION ON SYN GAS PRODUCTION FROM AGRO RESIDUE BRIQUETTE USING PLASMA ARC GASIFIER

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ABSTRACT

A thermo chemical conversion of agro briquettes into syn gas by plasma source for the gasification is known as plasma arc gasification. The proximate and elemental composition of agro briquettes are calculated using ASTM standards for the gasification study. The effect of steam in the plasma gasification on agro briquettes and syn gas generation are studied in plasma arc gasifier. The performance of the plasma gasifier is evaluated by finding the gas yield, heat value. The characterization of syn gas is also calculated at different steam flow rate. The experimental results are compared with those of literatures.

KEYWORDS: Agro Residues, Briquettes, Characterization, Plasma Gasification

INTRODUCTION

Agricultural residues have a great potential in most developing countries, since they are able to replace energy sources such as firewood. The power derived from agro residues is an important alternative and promising renewable for the sustainable development in the rural sector. One of the approaches that are being actively pursued worldwide towards improved and efficient utilization of agricultural and other biomass residues is their densification in order to produce pellets or briquettes. The briquetting of biomass improves its handling characteristics, increases the volumetric calorific value, reduces transportation costs and makes it available for a variety of applications. Gasification of agro briquettes is feasible to convert the biomass materials into gaseous energy but results in high ash and clinker formation. Plasma gasification uses an external heat source to gasify the waste, resulting in very little combustion and enhances the gasification process results in very less ash yield. Despite conventional biomass gasification, plasma gasification will be much appropriate method to gasify agro residues in efficient manner. This study is to perceive the suitability of the agro briquettes in plasma gasification.

MATERIALS AND METHODS

The knowledge of physical properties of the agricultural residues is of fundamental importance for proper design, dimensioning, manufacturing and operating different equipment used in processing operations. The agro briquettes are produced from agro residues like baggase, rice husk and turmeric plant stem through densification process. Proximate composition such as moisture, volatile matter, ash content and fixed carbon content of the agricultural residues briquette was calculated by ASTM standards D3172 – 75. Ultimate analysis such as Carbon, Hydrogen, Nitrogen and Oxygen of the

agricultural residues briquette was calculated by following ASTM standards E777-778 using a Carlo Ebra Elemental analyzer (EA 1108) coupled with an auto sampler (AS-200) and Data Processor (DP 200-PRC). The heat content of agricultural residue briquette was estimated as per standard (ASTM: D2015-77) procedure in bomb calorimeter (Adithya make, India). The gasification study is achieved in the plasma arc gasifier developed by Positronics India, Kolkata. The schematic representation of the plasma gasifier is represented in figure.1:.

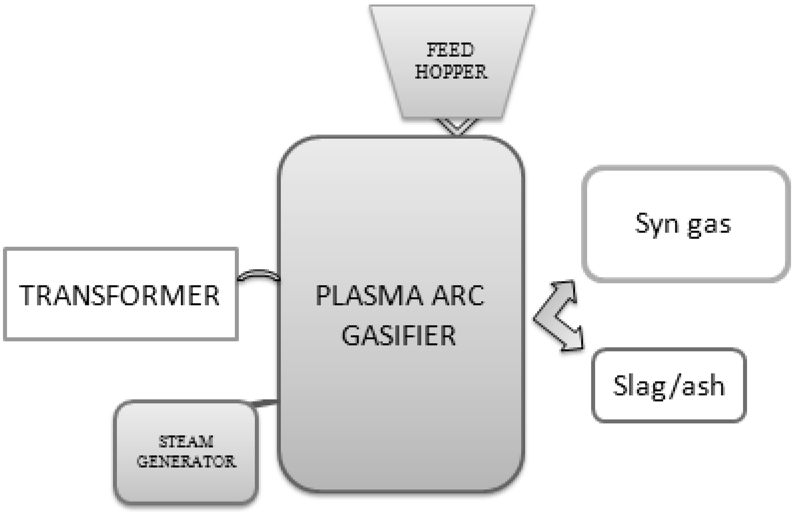

Figure 1: Schematic flow Chart of Plasma Arc Gasification Process

To understand the kinetic behaviour and weight loss of the agro residue during thermo chemical conversion, thermo gravimetric analysis and differential thermal analysis was studied under using Thermo gravimetric analyzer (TGA Q50). The thermo gravimetric analysis was carried out for the agro briquette at 40 °C min^{-1} heating rate for the degradation temperature of 800 °C using Nitrogen as a purge gas. Combustion gas analyzer to measure the components of syn gas produced from plasma gasifier at various time intervals.

RESULTS AND DISCUSSIONS

From the obtained values in the table 1:, it appears that the volatile content (61.87%), fixed carbon (18.11%), calorific value (27.43 MJ/kg) favours the gasification can be utilized for plasma gasification process. The upper acceptable limit of moisture content in biomass is generally considered to be 40 per cent on dry basis for gasification process (Dogru *et al.,* 2002). Higher the volatite content, higher the gasification efficiency. The optimum volatile content in biomass samples varies from 65 to 80 percent and it also expected to affect the overall gasification process similar to moisture content. During devolatilization, the agricultural residues undergo a thermal decomposition with subsequent release of the volatiles and the formation of tar and char.

Ash content is an important proximate composition in agro residues. Ash content less than 6 per cent is very significant in thermo chemical conversion process. Generally ash reacts to form a slag, a liquid phase formed at elevated temperatures, and leads to operational problems (Xiu *et al.,* 2005). The slag and clinker formation is less in very high temperature of plasma and ash content of 7.88 per cent can be easily manageable in plasma arc gasifier. The fixed carbon content around 20 per cent is significantly good to produce syn gas of 16-20 per cent carbon monoxide; hence this agro residue briquette is suitable for plasma arc gasification process.

Table 1: Proximate Composition of Agro Briquette

Proximate Composition	Agro Briquette
Moisture content, %	12.14
Volatile content, %	61.87
Ash content, %	07.88
Fixed carbon, %	18.11

The ultimate analysis of the agro residue briquette represents the Carbon (C), hydrogen (H), nitrogen (N) and oxygen (O) percentage content. The ultimate analysis and calorific value of agro residue briquette is presented in Table 2. The composition influences the heat content in the briquette. The higher in carbon proposition, compared with oxygen and hydrogen, increases in energy value of feed stock, due to the lower energy contained in carbon-oxygen and carbon-hydrogen bonds, than in carbon-carbon bonds. The agro briquette is having higher carbon content compared to oxygen and hydrogen proposition. The calorific value of briquette was found to be 27.43 MJ/kg, which is equivalent to wood feed material. The results represented in table 2 follows the results of Khardiwar et al., (2014).

Table 2: Ultimate Analysis and Heat Value of Agro Briquette

Ultimate analysis and heat value		Agro briquette
Ultimate analysis, %	Carbon	48.16
	Hydrogen	5.83
	Oxygen	40.11
	Nitrogen	4.89
Calorific value, MJ/kg		27.43

The thermo gravimetric analysis is usually used for thermal analysis of briquette during thermo chemical conversion process. Figure 2: shows the typical thermal decomposition curve for agro briquette. The initial loss in agro residue weight of about 6.23 per cent in temperature range of 25 – 175 °C was recorded due to moisture evaporation from the briquette. Because of low moisture content, the gasification characteristic of briquette was found to be better in plasma arc gasifier. Beyond this stage, a steep degradation was observed. The major weight loss (between 200 and 500 °C) is due to biomass volatilization and char oxidation processes. This second phase of curve indicates sudden drop due to the degradation of volatiles, which accounted about 89 per cent of total mass. The study matched with the results of Mohammed Said *et al.,* (2014), where the volatile degradation was 68.91 per cent and at 40 K min^{-1} heating rates respectively. At temperature of about 500 °C almost all the volatile matter was combusted from coconut husk and the weight loss was stabilized. After this temperature, there was gradual decrease in weight loss. It was due to oxidization of carbonaceous residues within inorganic solid particles, which progressed until 800 °C. The residue left over at the final temperature was found to be 6.03 per cent equates to ash content in the briquette. The thermal degradation curve was similar to the study by Prakash *et al.,* (2013).

The study in plasma arc gasifier indicated that under high temperature, the producer gas yield increases with decreasing in the yield of slag. The gas yield, gas composition, calorific value was studied with and without steam injection in the plasma gasifier by using agro briquettes as feed material and represented in the table 3: The experimental data of gas yield and heat content in the syn gas matches with the results of Rutberg *et al.,* (2011).

Table 3: Gas Yield and Calorific Value of Syn Gas from Plasma Arc Gasifier

Agro Briquettes		Gas yield,%	Calorific Value, MJ/Nm^3
Without steam injection		78.99	7.40
With Steam injection, kg/h	0.5	86.58	8.12
	1.0	87.48	8.40
	1.5	88.40	9.14
	2.0	88.75	8.75

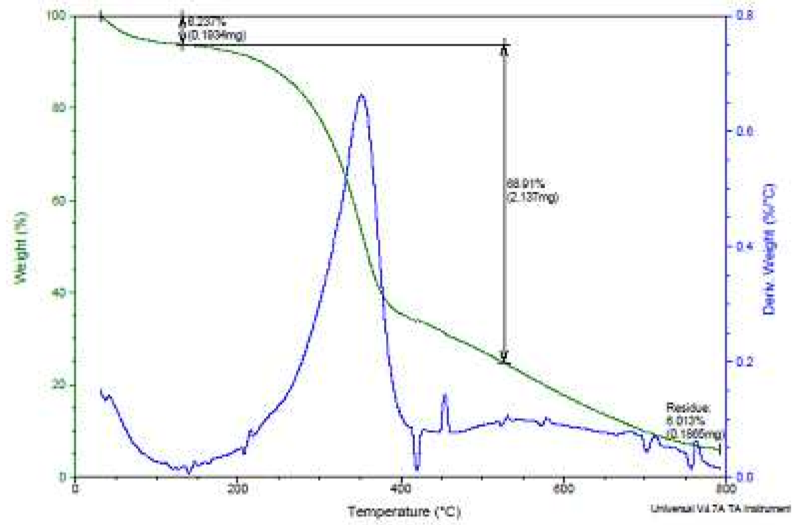

Figure 2: TGA Graph of Agro Briquette

The gas compostion of produced syn gas from the plasma arc gasifier at different mass flow rate of steam with constant quantity of feed stock fed through screw conveyor is in represented in the table 4.

Table 4: Gas Compostion of Syn Gas from Plasma Arc Gasifier

Agro Briquettes	Steam Flow Rate (Mass), kg/h	Syn Gas Composition, %			
		CO	H_2	CH_4	CO_2
Without steam injection	0.0	46.81	31.47	6.80	10.47
With Steam injection	0.5	32.85	47.74	8.97	8.78
	1.0	33.41	45.74	8.32	9.37
	1.5	42.67	35.11	9.80	6.47
	2.0	41.14	36.47	8.74	6.54

Application of energy supply by plasma in gasifier decreases the formation of H_2O and CO_2 and at the same time increases the percentage of CO, H_2 in the producer gas yield from the agro briquettes with and without steam injection for gasification process (Qinglin *et al.*, 2012). The study was proved by the experiments that syngas with high content of hydrogen and carbon monoxide can be obtained by plasma gasification with steam injection. The result coincides with the study of Huang and Tang, (2007) and Hrabovsky *et al.,* (2013) with steam plasma. The syngas composition can be controlled by a choice of steam flow rate. The syn gas composition with steam injection of 1.5 kg/h for 10 kg feed stock results in good quality of syngas with higher percentage of carbon monoxide (42.67) and methane (9.80). The plasma technologies for the thermolysis of biomass not only give high concentration of syngas, but also result in low concentration

of tar in gas phase mostly below 10 mg Nm^3 as noted by Hlina et al. (2006).

CONCLUSIONS

In this work, the agro briquettes have been investigated in plasma arc gasifier. The plasma gasification process offers considerable high energy recovery from agro residue briquettes when steam is used as a gasifiying agent. The performance of plasma gasifiers with and without high-temperature steam injection indicates that, plasma gasification is well suitable for heterogeneous agricultural briquettes with higher energy yield.

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